BRAND EVN

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Abstract A multi-band concurrent observation capability for the frequency bands commonly used in the EVN could greatly improve the VLBI scientific opportunities, even enabling an important simplification of the radio telescope operations. The project for a 1.5–15.5 GHz fully digital receiver is presented with possible solutions for a smooth introduction in the EVN radio telescopes, which differ widely from each other.

Keywords VGOS, EVN, DBBC, VLBI, backends

1 Introduction to the BRAND Project

Today EVN observing sessions are covered by separate receivers, and a sequence of about three or four bands per session are used in succession. Considering frequencies lower than 22 GHz the following bands are involved: 18 cm (L-band), 13 cm (S-band), 6 cm (C-band), 5 cm (C-band Methanol-OH), 4 cm (X-band), and at some stations even 2 cm (Ku-band) is available.

Having to use different physical receivers implies a number of restrictions including taking seconds to hours (depending on the radio telescope) to switch between bands, different mechanical positions at the antenna focus, more cryogenic cooling systems and receivers to be maintained, and different pointing models. So multi-band observations are not possible, while frequency agility in the EVN has been a high priority goal for more than 15 years. Compared to the VLBA, which has been offering fast frequency switching on the order of seconds since the beginning, this has obviously created a high user demand motivated by the possibility of saving valuable observing time, by the chance to obtain spectral index maps, and even more by the potential for precise registration of source positions via phase-referencing, which allows the measurement of frequency dependent core-shifts, and so on.

The new emerging geodetic network VGOS is implementing simultaneous multi-frequency observations. The goal for this network is to achieve an improved positioning accuracy down to 1 mm. To achieve this, fringe-fitting over a very-wide frequency range is applied, which includes an accurate determination of the ionosphere contribution.

The EVN can develop multi-wavelength VLBI now, starting a development that makes use of recent achievements in the relevant fields: existing implementations of broadband feeds and LNAs, backends with very high data rates (DBBC3 backend), and analog-to-digital converters which can sample the proposed frequency range. The latter will allow the introduction of new solutions where no frequency conversions are necessary to handle a huge sky frequency range. This will open a full set of new scientific opportunities such as real multi-wavelength VLBI mapping, multi-wavelength spectroscopy, multi-wavelength polarimetry, and multi-wavelength single-dish, geodetic VGOS compatibility. All of that would result in observing capabilities which are even superior to the fast frequency switching.

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2 Scientific Drivers

The implementation of a concurrent multi-band observing capability greatly enhances the potential for new scientific projects. This also offers an important simplification for the operation of the radio telescopes. It has an economic impact in the daily use and maintenance of the receiver systems.

In particular the scientific motivation for simultaneous multi-wavelength observations underlines the high priority of our project:

- VLBI mapping: using fringe-fitting over the whole band (including an ionospheric solution) will naturally allow precise registration of maps at different frequencies.
- VLBI spectroscopy: the simultaneous study of several different maser types in different frequency bands, and the alignment of different maser species allows, for instance, the determination of conditions in complex flow patterns.
- VLBI polarimetry: variations of polarized emissions as a function of frequency over a very wide frequency range can be measured, and precise rotation measures can be determined without ambiguities, which will improve studies of physical conditions of various astronomical objects.
- single dish: flux variation studies in several bands simultaneously (especially interesting for intraday variability) are possible, and rotation measures over large bandwidths can be made.
- compatibility with VGOS antennas: joint observations with geodetic VGOS antennas would be possible, for precise positions of astronomical antennas and celestial reference frame observations. Huge arrays for astronomical observations could be formed when needed.

In short, advantages could be envisaged for the EVN users: new improved science and additional available observing time due to the reduced/removed observation down-time. Advantages for the EVN telescopes are: having fewer receivers that require maintenance, more efficient use of the increased observing time, in addition to a reduction of daily cost for maintaining cooled receiver systems, and a simplification of their medium and long-term maintenance. EVN, like VGOS, could take the lead in VLBI observing because of the new multi-band simultaneous capability.

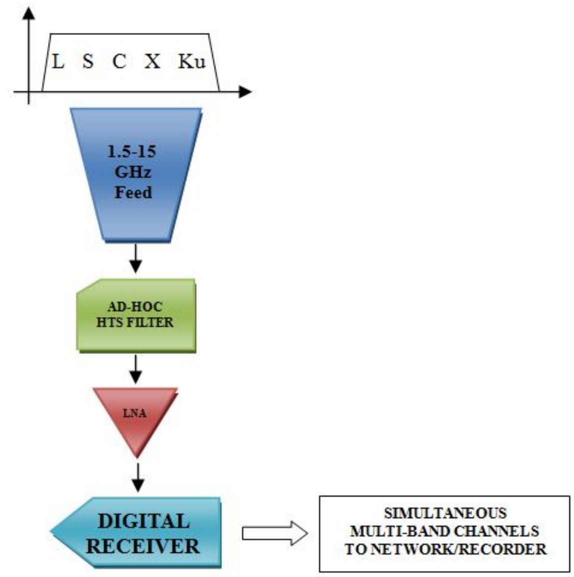

Fig. 1 Schematic view of the complete receiver.

3 Implementation

The BRAND project is a Joint Research Activity in the RadioNet4 proposal, which was submitted to the EU Horizon2020 call for proposals. In the BRAND project it is planned to develop a single cryogenic cooled receiver covering the broadband for astronomy with linear polarization feeds covering the frequency range 1.5–15 GHz. Figure 1 shows a schematic description of the proposed complete receiver system, including the analog front-end part (without any frequency conversion) and the broadband digital receiver.

The development work will take advantage of and start from state-of-the-art existing know-how, which will be adapted and extended for the EVN network. Here in summary, possible contributions of the various participants in the project are given with their expertise in the different parts of the project:

- Broadband antenna feed from ten years of technology developed for VGOS (OSO (QRFH), IGN (DYQSA))
- Low noise amplifiers developed for VGOS (MPI, IGN, IAF)
- Analog signal processing without any frequency conversion (INAF, MPI)

- Analog signal processing — only LNA and amplification chain with HTS filtering of strong RFI (INAF, MPI)
- Fully digital broadband sampling and data processing (DBBC3H INAF and MPI)
- Broadband digital receiver (INAF, MPI)
- Fully digital down-conversion and/or band selection with DSC/PFB/DDC modes (INAF, MPI)
- FPGA-based digital polarization conversion (ASTRON)
- Output channel selection and network routing/recording for multi-band simultaneous observations (INAF, MPI, OSO).

Different work packages are required to accomplish the project:

- Studies of the boundary conditions for antenna status of the EVN stations
- Determination of local RFI "fingerprints" at the EVN stations with homogeneous tools
- Ad-hoc development of the antenna feed
- Ad-hoc filtering implementation
- Broadband LNA development
- Broadband analog multi-bit to digital conversion
- Antenna system — digital receiver link connection
- Digital unit hardware implementation
- Method and implementation of digital polarization conversion from linear to circular
- Additional digital RFI mitigation firmware implementation
- Broadband DDC/PFB/DSC observing modes firmware implementation
- Multi-band total power detector firmware implementation
- Multi-band polarimeter firmware implementation
- Multi-band spectrometer firmware implementation
- Development of a complete prototype receiver for a selected antenna
- Integration and testing in the selected antenna
- Development of station control software
- Development of correlation and astronomical data processing software.

4 Conclusions

If the RadioNet4 proposal is successful, it might already start in December 2016, with a duration of four years. In RadioNet4, BRAND will develop a state-of-the-art digital receiver for radio astronomy, which, if deployed in the EVN, will change the way in which we do VLBI in Europe dramatically, opening new scientific opportunities. A great boost will be also given to the extreme wide-band technologies whose applications can be envisaged to bring possible benefits to the fields of telecommunication and diagnostic medical instrumentation.